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Quarterly Report

No. 7

LIFAC Sorbent Injection Desulfurization Demonstration Project

Presented By

LIFAC North America

A Joint Venture Between

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Presented To

U.S. Department of Energy

Pittsburgh Energy Technology Center
Pittsburgh, Pennsylvania 15236

April - June 1992

LIFAC SORBENT INJECTION
DESULFURIZATION DEMONSTRATION PROJECT

QUARTERLY REPORT NO. 7

APRIL - JUNE 1992

Submitted to

U. S. DEPARTMENT OF ENERGY

by

LIFAC NORTH AMERICA

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INTRODUCTION

In December 1990, the U.S. Department of Energy selected 13 projects for funding under the Federal Clean Coal Technology Program (Round III). One of the projects selected was the project sponsored by LIFAC North America, (LIFAC NA), titled "LIFAC Sorbent Injection Desulfurization Demonstration Project." The host site for this $22 million, three-phase project is Richmond Power and Light's Whitewater Valley Unit No. 2 in Richmond, Indiana. The LIFAC technology uses upper-furnace limestone injection with patented humidification of the flue gas to remove 75-85% of the sulfur dioxide (SO_2) in the flue gas.

In November 1990, after a ten (10) month negotiation period, LIFAC NA and the U.S. DOE entered into a Cooperative Agreement for the design, construction, and demonstration of the LIFAC system. This report is the seventh Technical Progress Report covering the period April 1, 1992 through the end of June 1992. Due to the power plant's planned outage schedule, and the time needed for engineering, design and procurement of critical equipment, DOE and LIFAC NA agreed to execute the Design Phase of the project in August 1990, with DOE funding contingent upon final signing of the Cooperative Agreement.

BACKGROUND

Project Team

The LIFAC demonstration at Whitewater Valley Unit No. 2 is being conducted by LIFAC North America, a joint venture partnership between:

- ICF Kaiser Engineers - A U.S. company based in Oakland, California, and a subsidiary of ICF International (ICF) based in Fairfax, Virginia.

- Tampella Power Corp. - A U.S. subsidiary of a large diversified international company, Tampella Corp., based in Tampere, Finland and the original developer of the LIFAC technology.

LIFAC NA is responsible for the overall administration of the project and for providing the 50 percent matching funds. Except for project administration, however, most of the actual work is being performed by the two parent firms under service agreements with LIFAC NA. Both parent firms work closely with Richmond Power and Light and the other project team members, including ICF Resources, the Electric Power Research Institute (EPRI), Indiana Corporation for Science and Technology (ICS&T), and Black Beauty Coal Company. LIFAC NA is having ICF Kaiser Engineers manage the demonstration project out of its Pittsburgh office, which provides excellent access to the DOE representatives of the Pittsburgh Energy Technology Center. Figure 1 shows the management structure being used throughout the three phases of the project.

LIFAC NA administers the project through a Management Committee that decides the overall policies, budgets, and schedules. All funding sources, invoicing, and information flows to LIFAC NA where the managing partners ensure that the project, funding and expenditures are consistent and in-line with the established policies, budgets, schedules and procedures.

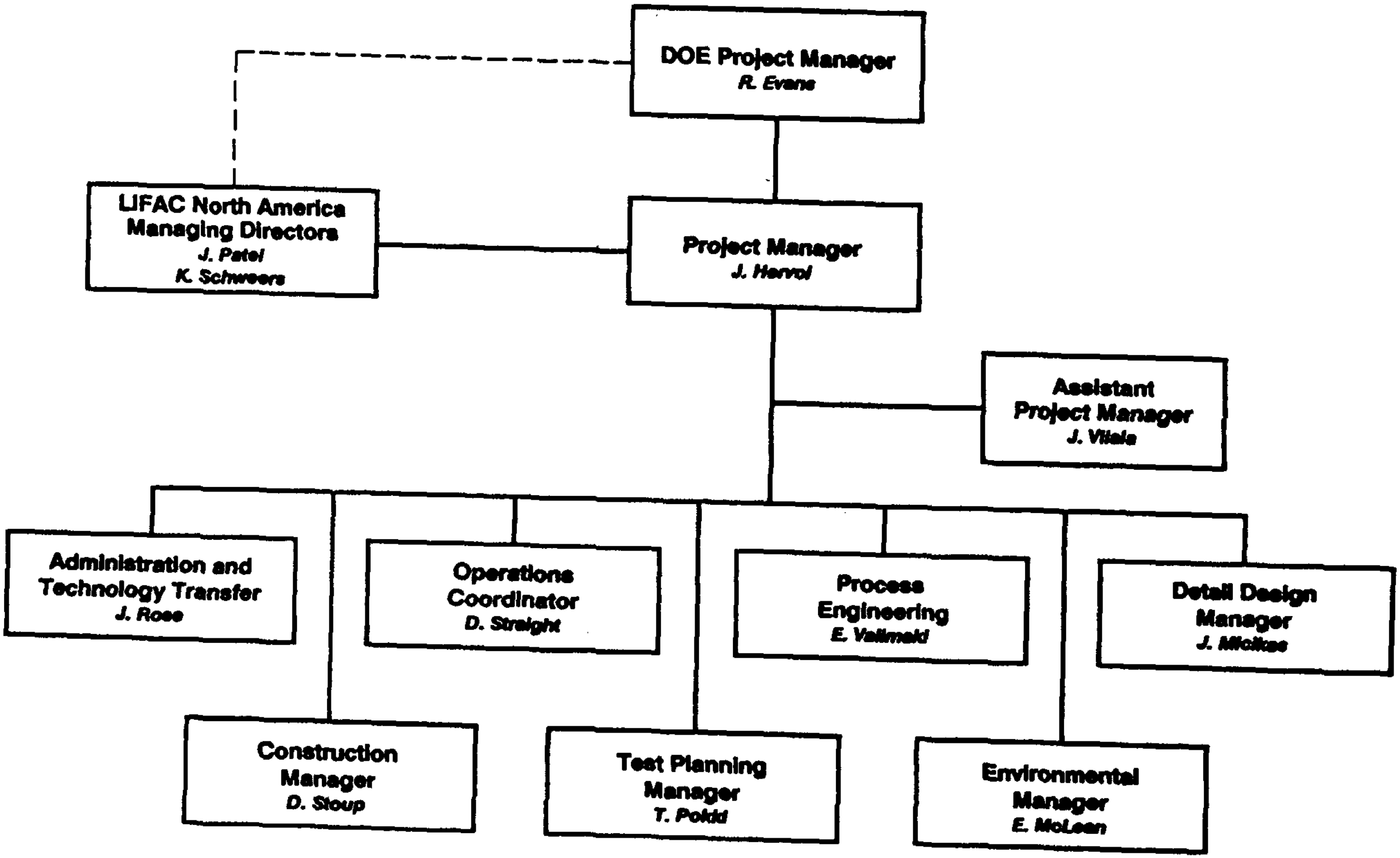
Process Development

In 1983, Finland enacted acid rain legislation which applied limits on SO_2 emissions sufficient to require that flue gas desulfurization systems have the capability to remove about eighty percent (80%) of the sulfur dioxide in the flue gas. This level could be met by conventional scrubbers, but could not be met by then available sorbent injection technology. Therefore, Tampella began developing an alternative system which resulted in the LIFAC process.

Initially, development included laboratory-scale and pilot-plant tests. Full-scale limestone injection tests were conducted at Tampella's Inkeroinen facility, a 160 MW coal-fired boiler using high-ash, low-sulfur Polish coal. At Ca:S ratios of 3:1, sulfur removal was less than 50%. Better results could have been attained using lime, but was rejected because the cost of lime is much higher than that of limestone.

In-house investigations by Tampella led to an alternative approach involving humidification in a separate vertical chamber which became known as the LIFAC Process. In cooperation with Pohjolan Voima Oy, a Finnish utility, Tampella installed a full-scale limestone injection facility on

Project Organization



a 220 MW coal-fired boiler located at Kristiinankaupunki. At this facility, a slipstream (5000 SCFM) containing the calcined limestone was used to test a small-scale activation reactor (2.5 MW) in which the gas was humidified. Reactor residence times of 3 to 12 seconds resulted in SO_2 removal rates up to 84%. Additional LIFAC pilot-scale tests were conducted at the 8 MW (thermal) level at the Neste Kulloo combustion laboratory to develop the relationships between the important operating and design parameters. Polish low-sulfur coal was burned to achieve 84% SO_2 removal.

In 1986, full-scale testing of LIFAC was conducted at Imatran Voima's Inkoo power plant on a 250 MW utility boiler. An activation chamber was built to treat a flue gas stream representing about 70 MW. Even though the boiler was 250 MW, the 70 MW stream represented about one-half of the flue gas feeding one of the plant's two ESP's (i.e., each ESP receives a 125 MW gas stream). This boiler used a 1.5% sulfur coal and sulfur removal was initially 61%. By late 1987, SO_2 removal rates had improved to 76%. In 1988, a LIFAC activation reactor was added to treat an additional 125 MW -- i.e., an entire flue gas/ESP stream-worth of flue gas from this same boiler. This newer activation reactor is achieving 75-80% SO_2 removal with Ca:S ratios between 2:1 and 2.5:1. In 1988, the first tests using high-sulfur U.S. coals were run at the pilot scale at the Neste Kulloo Research Center, using a Pittsburgh No. 8 coal containing 3% sulfur. SO_2 removal rates of 77% were achieved at a Ca:S ratio of 2:1.

This LIFAC demonstration project will be conducted on a 60 MW boiler burning high-sulfur U.S. coals to demonstrate the commercial application of the LIFAC process to U.S. utilities.

Process Description

LIFAC combines upper-furnace limestone injection followed by post-furnace humidification in an activation reactor located between the air preheater and the ESP. The process produces a dry and stable waste product that is partially removed from the bottom of the activation reactor and partially removed at the ESP.

Finely pulverized limestone is pneumatically conveyed and injected into the upper part of the boiler. Since the temperatures at the point of injection are in the range of 1800-2000° F, the limestone ($CaCO_3$) decomposes to form lime (CaO). As the lime passes through the furnace, initial desulfurization reactions take place. A portion of the SO_2 reacts with the CaO to form calcium sulfite ($CaSO_3$), part of which then oxidizes to form calcium sulfate ($CaSO_4$). Essentially all of the sulfur trioxide (SO_3) reacts with the CaO to form $CaSO_4$.

The flue gas and unreacted lime exit the boiler and pass through the air preheater. On leaving the air preheater, the gas/lime mixture is directed to the patented LIFAC activation reactor. In the reactor, additional sulfur dioxide capture occurs after the flue gas is humidified with a water spray. Humidification converts lime (CaO) to hydrated lime, $Ca(OH)_2$, which enhances further SO_2 removal. The activation reactor is designed to allow time for effective humidification of the flue gas, activation of the lime, and reaction of the SO_2 with the sorbent. All the water droplets evaporate before the flue gas leaves the activation reactor. The activation reactor is also designed specifically to minimize the potential for solids build-up on the walls of the chamber. The net effect is that at a Ca:S ratio in the range of 2:1 to 2.5:1, 70-80% of the SO_2 is removed from the flue gas.

The flue gas leaving the activation reactor then enters the existing ESP where the spent sorbent and fly ash are removed from the flue gas and sent to the disposal facilities. ESP effectiveness is also enhanced by the humidification of the flue gas. The solids collected by the ESP consist of fly ash, $CaCO_3$, $Ca(OH)_2$, CaO, $CaSO_4$, and $CaSO_3$. To improve utilization of the calcium, and increase SO_2 reduction to between 75 and 85%, a portion of the spent sorbent collected in the bottom of the activation reactor and/or in the ESP hoppers is recycled back into the ductwork just ahead of the activation reactor.

Process Advantages

The LIFAC technology has similarities to other sorbent injection technologies using humidification, but employs a unique patented vertical reaction chamber located down-stream of the boiler to facilitate and control the sulfur capture and other chemical reactions. This chamber improves the overall reaction efficiency enough to allow the use of pulverized limestone rather than more expensive reagents such as lime which are often used to increase the efficiency of other sorbent injection processes.

Sorbent injection is a potentially important alternative to conventional wet lime and limestone scrubbing, and this project is another effort to test alternative sorbent injection approaches. In comparison to wet systems, LIFAC, with recirculation of the sorbent, removes less sulfur dioxide - 75-85% relative to 90% or greater for conventional scrubbers - and requires more reagent material. However, if the demonstration is successful, LIFAC will offer these important advantages over wet scrubbing systems:

- LIFAC is relatively easy to retrofit to an existing boiler and requires less area than conventional wet FGD systems.
- LIFAC is less expensive to install than conventional wet FGD processes.
- LIFAC's overall costs measured on a dollar-per-ton SO_2 removed basis are less, an important advantage in a regulatory regime with trading of emission allocations.
- LIFAC produces a dry, readily disposable waste by-product versus a wet product.
- LIFAC is relatively simple to operate.

HOST SITE DESCRIPTION

The site for the LIFAC demonstration is Richmond Power and Light's Whitewater Valley 2 pulverized coal-fired power station (60 MW), located in Richmond, Indiana. Whitewater Valley 2, which began service in 1971, is a Combustion Engineering tangentially-fired boiler which uses high-sulfur bituminous coal from Western Indiana. Actual power generation produced by the unit approaches 65 megawatts. As such, it is one of the smallest existing, tangentially-fired units in the United States. The furnace is 26-feet, 11-inches deep and 24-feet, 8-inches wide. It has a primary and secondary superheater. Tube sizes and spacings are designed to achieve the highest possible heat-transfer rates with the least potential for gas-side fouling. The unit also has an inherent low draft-loss characteristic because of the lack of gas turns. At full load 540,000 lbs/hr. of steam are generated. The heat input at rated capacity is 651 x 10^6 Btu per hour. The design superheater outlet pressure and temperature are 1320 psi at 955°F. The unit has a horizontal shaft basket-type air preheater. The temperature leaving the economizer is about 645°F, while the stack gas temperature is about 316°F. The balanced-draft unit has 12 burners.

In 1980 the unit was fitted and fully optimized with a state-of-the-art Low-NO_x Concentric Firing System (LNCFS). The LNCFS represents a very cost effective means of reducing NO_x emissions in comparison with other retrofit possibilities. The system works on the principal of directing secondary air along the sides of the furnace and creating a fuel rich zone in the center of the furnace. With the LNCFS, the excess air can be maintained below 20 percent. Additionally, the installation reduces ash accumulation on the furnace walls increasing heat absorption and reducing attemperation requirements. With the LNCFS, each corner of the furnace has a tangential windbox consisting of three coal compartments and four auxiliary air compartments. At full load with all three 593 RB pulverizers operating, primary transport air from the pulverizers amounts to 23 percent of the total combustion air. Pulverizer capacity is 26,400 lbs/hr. with 52 grind coal and 70 percent minus 200 mesh.

Whitewater Valley 2 has a Lodge Cottrell cold side precipitator which was erected with the boiler. The precipitator treats 227,000 actual cubic feet per minute of 316°F flue gas with 45,000 square feet of collection area. The unit has two mechanical fields and four electrical fields and achieves 99 percent removal efficiency (from 3.9 gr/ft^3 to 0.04 gr/ft^3). The ESP performance was optimized by Lodge Cottrell when Richmond Power and Light purchased new controllers in 1985.

Whitewater Valley Unit 2's overall efficiency of 87.47 percent at full load has shown little variation over the years. The unit's average heat rate is 10,280 Btu/Kwh. At 60 percent of full load, the unit's efficiency increases to 88.17 percent. The unit uses approximately 0.935 pounds of coal per Kwh and generates 8.51 pounds of steam per Kwh.

The primary emissions monitored at the station are SO_2 and opacity. SO_2 emissions are calculated based on the coal analysis and are limited to 6 lbs/MBtu. Opacity is monitored using an in-situ meter at the stack and is currently limited to 40 percent. Current SO_2 emissions for the unit are approximately 4 lbs/MBtu, while opacity at full load ranges from 15 to 20 percent. Opacity at low load (40MW) ranges from 3 to 5 percent. Limited testing was conducted in November of 1986 for NO_x emissions. Results from the test work indicated that NO_x emissions averaged 0.65 lbs/MBtu.

Whitewater Valley 2 has several important qualities as a LIFAC demonstration site. One of these is that Whitewater Valley 2 was the site of a prior joint EPA/EPRI demonstration of LIMB sorbent injection technology. Much of the sorbent injection equipment remains on site and will be used in the LIFAC demonstration, if possible. Another advantage of the site is that Whitewater Valley 2 is a challenging candidate for a retrofit due to the cramped conditions at the site. The plant is thus typical of many U.S. power plants which are potential sites for application of LIFAC. In addition, the Whitewater Valley 2 boiler is small relative to its capacity; hence, it has high-temperature profiles relative to other boilers. This situation will require sorbent injection at higher points in the furnace in order to prevent deadburning of the reagent and may decrease residence times needed for sulfur removal. Whitewater Valley 2 will show LIFAC's performance under operational conditions most typical of U.S. power plants. The project will demonstrate LIFAC on high-sulfur U.S. coals and is a logical extension of the Finnish demonstration work and important for LIFAC's commercial success in the U.S.

PROJECT SCHEDULE

To demonstrate the technical viability of the LIFAC process to economically reduce sulfur emissions from the Whitewater Valley Unit No. 2, LIFAC NA is conducting a three-phase project.

Phase I: Design
Phase IIA: Long Lead Procurement
Phase IIB: Construction
Phase III: Operations

Except Phase IIA, each phase is comprised of three (3) tasks, a management and administration task, a technical task and an environmental task. The design phase began on August 8, 1990 and was scheduled to last six (6) months. Phase IIA, long lead procurement, overlaps the design phase and was expected to require about four (4) months to complete. The construction phase was then to continue for another seven (7) months, while the operations phase was scheduled to last about twenty-six (26) months. Figure 2 shows the original estimated project schedule which is based on a August 8, 1990 start date and a planned outage of Whitewater Valley 2 during March 1991.

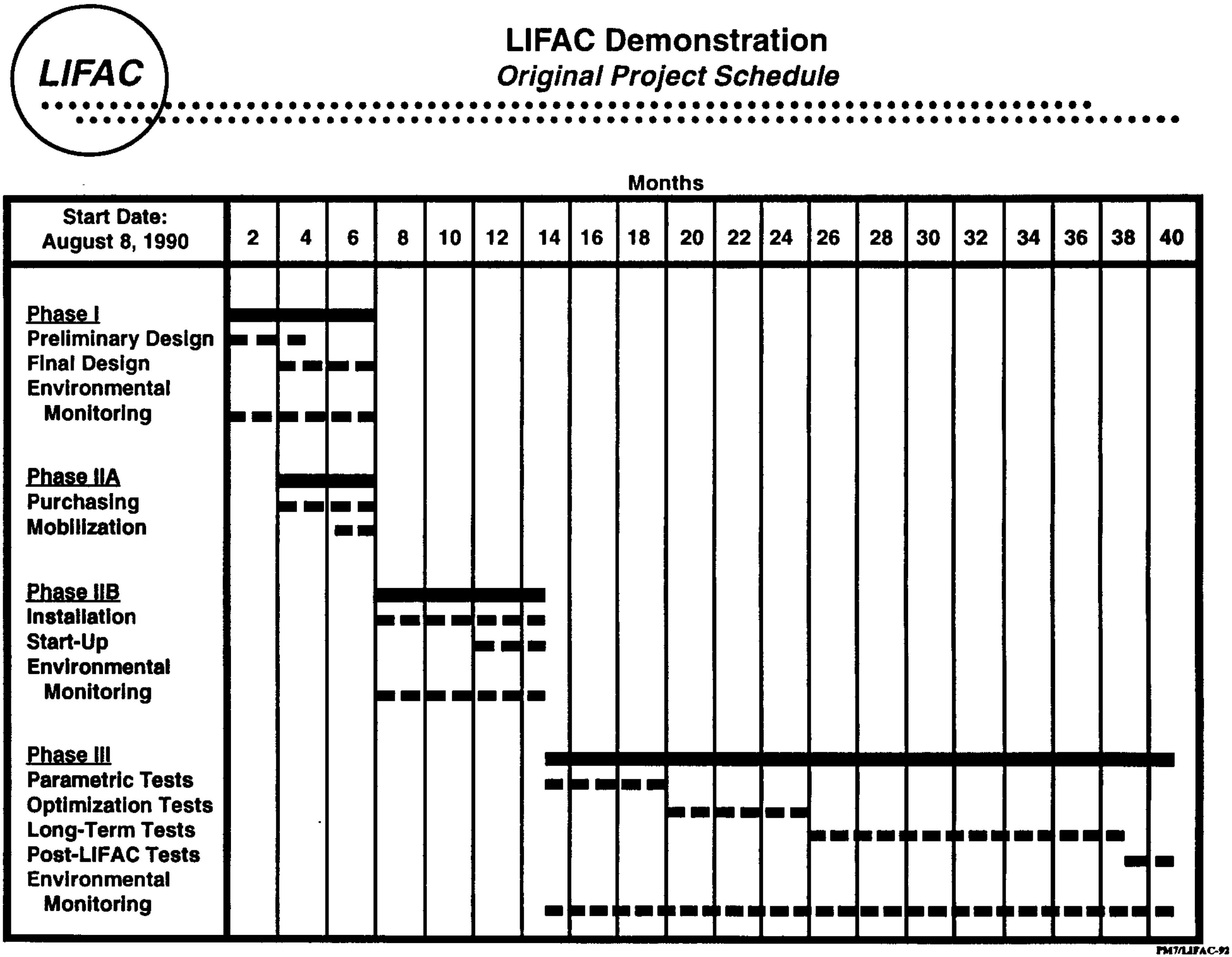
It is during this outage that all the tie-ins and modifications to existing Unit No. 2 equipment were made. This required that the construction phase begin in early February, 1991 -- construction was to be completed by the end of August 1991. Operations and testing were to begin in September 1991 and continue for 26 months. However, during previous reporting periods, the project encountered delays in receiving its construction permit. These delays, along with some design changes, and an approved expansion in project scope required that the Design Phase be extended by about eleven months. Therefore, construction was not completed until early June 1992. This represents a nine-month extension in the overall schedule. Figure 3 shows the revised project schedule. Total project duration will now be 48 months.

TECHNICAL PROGRESS

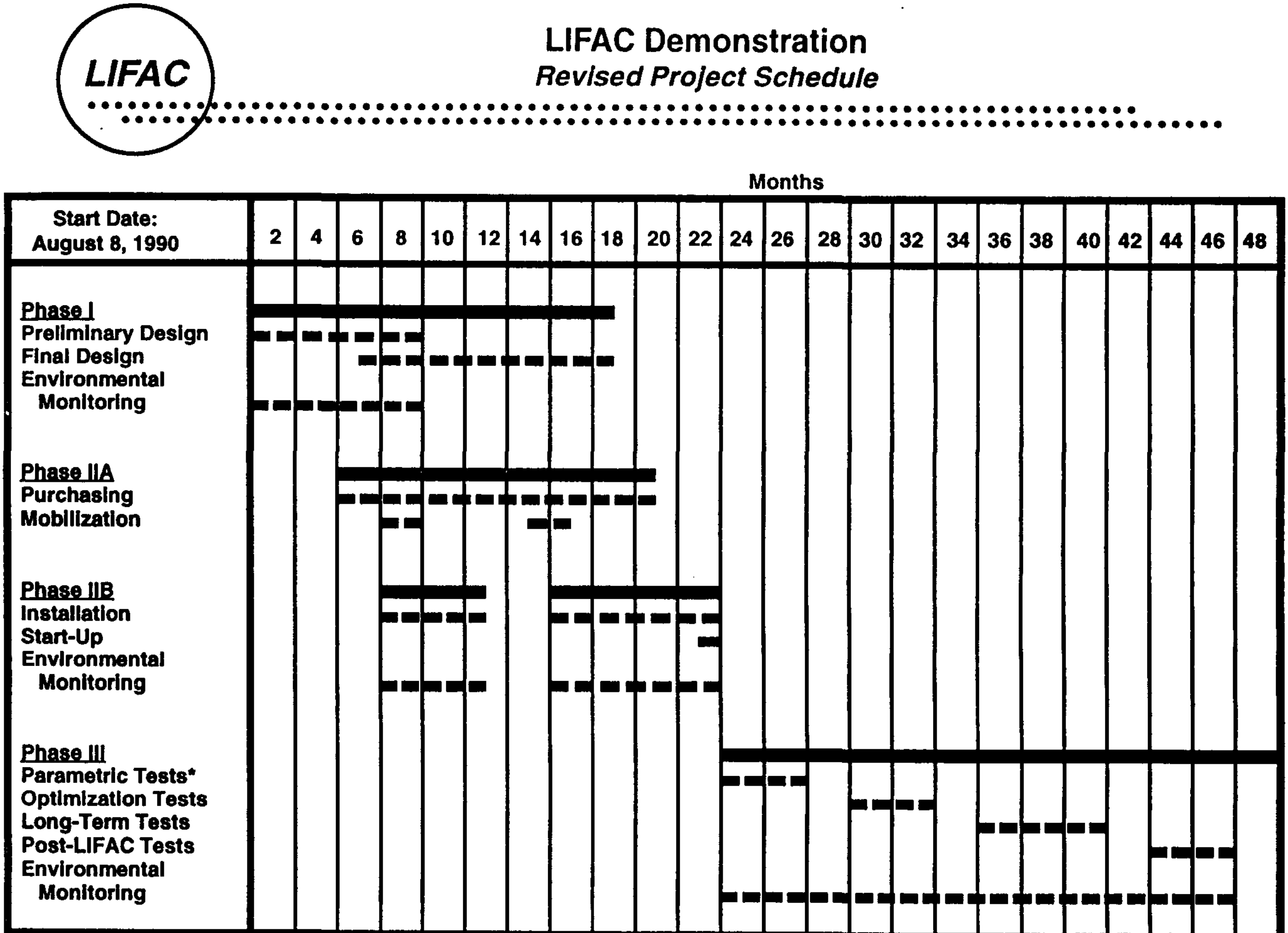
The work performed during this period (April - June 1992) was consistent with the revised Statement of Work (Scope Increase) and the approved

LIFAC Demonstration

Original Project Schedule



LIFAC Demonstration
Revised Project Schedule



* Includes baseline testing.

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schedule change contained in the Cooperative Agreement. During this period, emphasis was placed on completing the Construction Phase and start-up of the Operation Phase. Work was conducted under six different tasks. Following is a summary of the work performed under these tasks.

Project Management (WBS 1.2.1B and WBS 1.3.1)
During the April through June 1992 period, management efforts and achievements included:

- **LIFAC Management Committee Meeting #8 -** The LIFAC management committee held its eighth formal management committee meeting on April 29, 1992 at the ICF Kaiser Engineers' office in Pittsburgh, Pennsylvania. The agenda of this meeting included:

  - The project managers of ICF Kaiser Engineers and Tampella Power reported that they expected to finish Budget Period I on time (i.e. in June 1992) and within the revised budget recently approved by DOE.

  - The committee discussed both Period I and Period II budget issues, and requested a more detailed review of the Period II budget to be held at a future meeting.

  - The committee heard reports on regulatory and permitting developments.

  - The committee also heard reports related to fulfillment of the DOE Cooperative Agreement including the numerous reports required at the end of Budget Period I, etc.)

- **LIFAC Management Committee Meeting #9 -** The LIFAC management committee held its ninth formal management committee meeting on June 2, 1992 via phone conference involving staff in Atlanta, Pittsburgh and Fairfax. The agenda of this meeting included:

  - The committee authorized ICF Kaiser Engineers and Tampella Power to begin Period II and to continue to work through the end of July even if DOE did not immediately approve the initiation of Period II. The committee recognized that this work would be at risk, but considered DOE approval to be extremely likely.

- The project managers of ICF Kaiser Engineers and Tampella Power reported that Budget Period I would end on time, five days hence on June 7, 1992, and within budget. Most work except some electrical work and VFD upgrading was complete.

- The committee heard reports on regulatory and permitting developments.

• **LIFAC Management Committee Meeting #10** - The LIFAC management committee held its tenth formal management committee meeting on June 23, 1992 at the Richmond Power and Light headquarters in Richmond, Indiana. The agenda of this meeting included:

  - The committee toured the site, and expressed satisfaction with the completion of the construction phase.

  - The committee met with the General Manager of the host utility who also expressed satisfaction with the progress to date.

  - The committee checked on the status of DOE approval for Budget Period II. At the previous meeting, they authorized the work to continue to end of July even without formal DOE approval; DOE approval was considered imminent.

  - The project managers of ICF Kaiser Engineers, and Tampella Power reported that some minor electrical work and VFD upgrading was still ongoing, but that testing start up had commenced.

  - The committee reviewed detailed Budget Period II manpower and budget cost estimates.

- **Joint LIFAC NA/DOE Cooperation** - For this period, LIFAC NA successfully implemented the Cooperative Agreement's management, administrative and technical provisions including DOE reporting and administrative requirements:

  - The project reviewed progress on the numerous reports associated with the completion of Budget Period I and the commencement of Budget Period II including the Project Evaluation Plan, Project Evaluation Report, Test Plan, Start-up Plan, Environmental Monitoring Plan (EMP), Continuation Application, and Design Report.

  - LIFAC NA provided to DOE required financial, project and cost reports including: (1) monthly technical progress, (2) cost management, and (3) federal assistance management summary reports.

  - LIFAC NA sent invoices to DOE during the period consistent with DOE requirements that the project report invoiced costs on a phase-by-phase basis.

- **Regulatory** - Overall, in the previous period, the project made significant progress resolving regulatory problems (e.g. receipt of the solid waste disposal letter from IDEM). However, due to the importance of this area, the LIFAC Management Committee continued to manage/oversee, and in some cases, directly participate (e.g. meeting with regulatory attorneys) in the permitting and approvals process. The environmental regulatory situation, discussed further elsewhere, is summarized here:

  - At the end of the previous quarter, IDEM agreed in principle to provide a TSP emission variance in response to an RP&L variance request filed in the third quarter of 1991. RP&L needed this variance, which would allow increased particulate emission limits, independent of the LIFAC process, but the utility included a clause into the request specifically addressing the LIFAC demonstration.

During this quarter, IDEM and other parties conducted and concluded negotiations on the terms of the variance, and IDEM issued the variance for LIFAC operation.

- In parallel, RP&L was in contact with EPA Region V with regard to TSP emissions. LIFAC NA closely monitored developments in this area.

- **Funding Agreements** - LIFAC NA continued efforts to negotiate and finalize arrangements for participation/funding of other project participants:

  - Electric Power Research Institute - LIFAC NA project managers conferred with representatives of EPRI to discuss EPRI funding. More information on funding and technical assistance is expected in the next reporting period.

  - Indiana Corporation for Science and Technology (CST) - LIFAC NA received all remaining funding during this period.

  - Black Beauty Coal Company - LIFAC NA believes that Black Beauty will provide most of the coal for the test program and replace the coal expected from Peabody Coal Company. LIFAC NA will continue to negotiate a contribution from Black Beauty towards the project.

- **Technology Transfer Activities** - During the quarter, LIFAC NA and DOE jointly worked on several drafts of joint papers for presentation at the Pittsburgh coal conference to be held in Pittsburgh this fall, and for a conference to be held in Atlanta.

Installation and Startup (WBS 1.2.2B)

During this period, emphasis was placed on obtaining mechanical completion. ICF Kaiser Engineers' four subcontractors continued work on the three main areas:

- **Limestone Storage Area** - All mechanical work in this area was completed in early June as follows:

  - Painting of limestone storage bin was finished.
  - All exhaust fans, louvers, unit heaters, HVAC units and lights were installed.
  - All piping was installed, tested and painted.
  - All instrumentation was installed and system checkouts started.
  - All existing mechanical equipment (blowers, compressors, pump, rotary valve) was checked and/or serviced.
  - Except for lighting, all electrical requirements were completed and are in process of testing.
  - The VFD was started and is currently being de-bugged.
  - Punchlist items are being resolved.

- **Boilerhouse/ESP Area**

  - All structural steel was erected.
  - The recycle equipment was received and installed.
  - Recycle piping reached about 90% complete.
  - Compressed air and humidification water piping installed complete and tested.
  - Secondary air duct, limestone injection nozzles and transport piping installed complete.
  - All electrical control wiring complete except for recycle equipment in ESP area.
  - Startup, checkout and calibration of all equipment (except ESP area) in process.

- **Reactor Area**
  - All structural steel was erected complete.
  - The reactor was erected, tested, insulated and jacketed complete.
  - The reactor building siding, insulation, roof and trim were completed.
  - All mechanical equipment and HVAC units were installed.

- All steam, water, condensate and compressed air piping was installed and is in process of being tested.
- The flue gas duct system was installed insulated and jacketed complete.
- Instrumentation is about 90% installed.
- Electrical control wiring is about 75% complete.

Testing and Data Analysis (WBS 1.3.2)

Work under this task was initiated towards the end of this reporting period. Efforts were made to begin mechanical and electrical startup and checkout in the three main areas:

- **Limestone Storage Area** - The primary goal this period was to have all the existing sorbent injection equipment checked out and calibrated by the equipment manufacturers. All the existing equipment was tested and operated except for the existing blowers. Upon detailed inspection by the manufacturer, it was determined that the existing blowers were beyond economic repair. A new blower was ordered and is expected to be installed early next period. All other electrical/instrumentation systems were checked in preparation of receiving the first load of limestone.

- **Boilerhouse/ESP Area** - Mechanical and electrical checkout were completed on the new boiler injection nozzles, the secondary air fan, the humidification pump and the process control system. Installation of the ESP recycle equipment was not completed this period. Installation and checkout will be completed next period. The insitu flue gas analyzers were installed and calibrated and were placed in service in preparation of baseline testing.

- **Reactor Area** - Once installation of the reactor was complete, the reactor was tested with cold air and hot flue gas to determine if any thermal expansion problems existed. The reactor vessel checked out satisfactorily. The reactor bottom ash conveyors were tested, and a problem was encountered in one of the drive sprockets on one of the crushers. A new sprocket had to be fabricated. It will be replaced next reporting period.

By the end of this reporting period, about 50% of all mechanical and electrical startup and checkout was complete.

Also, during this period, coal and limestone suppliers were identified and agreements placed in service for delivery and costs.

Environmental Monitoring (WBS 1.2.3B and WBS 1.3.3)
During this period, emphasis was placed on two activities:

- **Environmental Monitoring Plan** - The final EMP was prepared and submitted to DOE for approval. Formal approval of the Plan was received in June. As part of the environmental monitoring effort, competitive bids were received for analytical services and for stack testing. Subcontracts were put in place so that these services would be available during baseline testing.

- **Operating Permit** - Also in June, the Indiana Department of Environmental Management issued the formal operating permit to RP&L allowing operation of LIFAC under a variance for particulate emissions.

FUTURE PLANS

During the next reporting period, emphasis will be placed on the following activities:

- Complete all mechanical and electrical startup and checkout.
- Complete baseline testing.
- Begin parametric testing.
- Present two technical papers at conferences and exhibits.
- Continue submitting the reports required under the Cooperative Agreement.
- Resolve any problems encountered during startup and checkout.